

# Hex-Chrome Free Hardware - BAE Experience

## ASSETSDefense: DoD Vehicle Workshop Grand Rapids, Michigan

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# About BAE Systems

- Global defense and aerospace company delivering a full range of products and services for air, land and naval forces, as well as advanced electronics, information technology solutions and customer support services.
- Largest European defense company.
- Fifth-largest U.S. defense company.
- Sales exceeded \$34.4 billion in 2008.
- Invests over \$2.3 billion annually on research and development.
- Approximately 105,000 employees worldwide.
- BAE Systems, Inc. is a U.S. company, reporting to BAE Systems, plc in the UK via a Special Security Agreement (SSA).



# Tracked vehicles



Bradley Fighting Vehicle



CV90



Hercules



Warrior



AAV



Armored Medical Evacuation Vehicle



Challenger II



Bv206S



BvS10



Bulldog



M113 Family of Vehicles



ACV 300



Trojan



Terrier



Titan



FAASV



MLRS (CHASSIS)



M9 ACE

# Wheeled vehicles



FMTV



JLTV (GTS)



JLTV (USCS)



RG-35



Armored Commercial Vehicles



RG-33 4x4



RG-33 6x6 MMPV



Up-Armored Humvee



Caiman MRAP



RG-12



RG-31 Mk5



Panther



RG-31 Mk6



Tactica



RG-31 Ambulance



RG-32 M

# Artillery systems



Paladin PIM



Archer



M777



FH-77



AS90



Light Gun



M109 Family of Vehicles



HIMARS (CHASSIS)

# Naval weapon systems



Advanced Gun System



Mk38 Mod 2



Mk45 Mod 4



Mk110 Mod 0



VLS Mk41

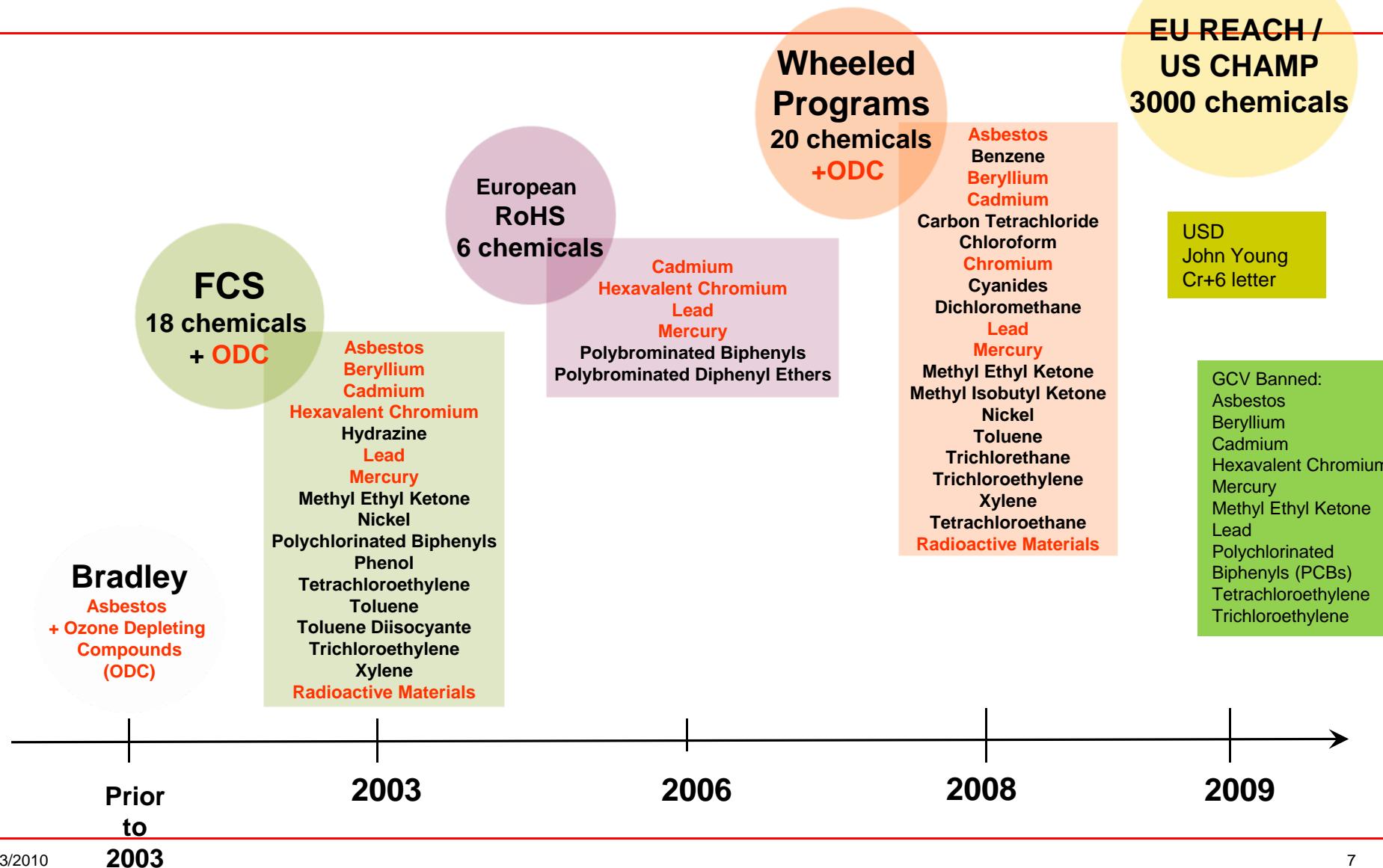


VLS Mk57



155mm TMF

# PROHIBITED MATERIALS TREND



# Hexavalent Chrome

- **Banned on Some New Contracts**
  - USD John Young Memo
- **Most common usage is as a conversion coating for metals to enhance corrosion performance**
  - **Very commonly used on aluminum, zinc, and cadmium**
  - **Most common specs:**
- **ASTM B633 Type II** (electrodeposited zinc coating) uses hexavalent chrome (chromate) conversion coating
  - After eliminating cadmium plating, zinc plating was substituted
    - Note also similar conversion coatings used for cadmium, zinc nickel, aluminum coatings, etc.
  - **ASTM B633 Type VI** allows use of non-hexavalent chromium (trivalent chrome or others)
- **MIL-DTL-5541** (aluminum)
  - New Type II specified as hex chrome free
  - Typically specified as part of the paint system
  - Supply base is changing over

TABLE 2 Finish Type and Corrosion Resistance Requirements

Type	Description	Minimum Salt Spray h
I	As-plated without supplementary treatments	
II	With colored chromate coatings	96
III	With colorless chromate conversion coatings	12
IV	With phosphate conversion coatings	
V	With colorless passivate	72
VI	With colored passivate	120

NOTE 3—Although Types V and VI are technically not “chromate” films and they do not contain leachable hexavalent chromium ions, they are supplemental coatings that render the active zinc surface passive and provide added protection to the steel part.

# BAE Combat Systems “Clean Hardware” Initiative

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- US Army wants non-hazardous materials and better corrosion performance for their platforms
- DoD direction to improve corrosion performance
  - 20-30 year service life required
- New wheeled (MMPV, MATV) and GCV programs prohibited from using hexavalent chrome
  - Common yellow/gold finish on plated hardware
- No commercially available off-the-shelf replacement available, although numerous coatings are available (not on shelf)
- BAE CS selected Dip-Spin zinc/aluminum-epoxy coating as environmentally friendly substitute with very good torque and corrosion performance

# ARL Test Report

- 120 Cycles GM 9540 cyclic salt spray test
  - Roughly equivalent to 15 years service in humid environment
  - Threaded into steel and aluminum
  - Inspected every 20 cycles
  - Break away torque measured
- Final performance ranking:
  1. Magni 565
  2. Magni 594
  3. Alumiplate
  4. Hex Chrome Zinc plate
  5. Trivalent Chrome Zinc

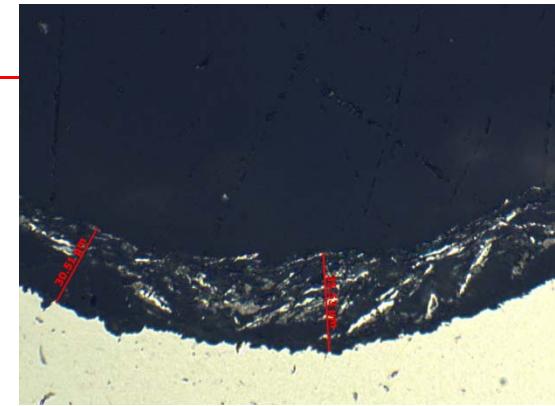


Baseline Zinc / Trivalent Zinc / Alumiplate / Magni 565 / Magn 594  
Courtesy of ARL

# Magni 565 what is it?

- Zinc Rich epoxy base coat
- Aluminum rich epoxy top coat
  - Dip/spin coating (generic designation)
  - Part is cleaned and phosphated, immersed in liquid coating, then spun (washing machine spin cycle) then spread on conveyor belt and baked
- Compatible with both steel and aluminum assemblies
- 1000 hour salt spray resistance (vs 96 for zinc)
- Torque-tension coefficient same as Cadmium
- No plating, freedom from hydrogen embrittlement
- Cost is comparable to Type II chromate zinc
  - But much better corrosion performance
- Wide use by automotive companies

- Automotive Qualifications
  - ASTM F1137 Type 3
  - Bobcat PS-106A
  - BMW GS90010
  - Briggs & Stratton
  - Case New Holland MAT0320, Type 1, Class A
  - Chrysler PS-5873 (ref: PS-10633 non-threaded), PS-10633, PS-10378
  - Daimler-Benz DBL 8440
  - Delphi DX551801, DX45501804, DX551810, DX44501804
  - Fiat 9.57513/Tipo IV
  - Ford S439 (WSS-M21P37-A1)
  - General Motors GM7114M, GMW3359
  - Int'l Truck TMS-4518, Type I
  - ISO 10683
  - JLG 4150701
  - John Deere JDM F13
  - Land Rover LRES.21.ZS.05
  - Nissan M4601
  - Porsche PTL 7529
  - PSA B15 3320
  - Renault Trucks 01.71.4002/H
  - Tacom/US Army 12469117
  - Toro
  - Trane S 3201063A1
  - TRW TS 2-25-60, Class A
  - Volkswagen TL 233
  - Volvo VCS5737.29, .19



Magni is one of several coatings, others such as Geomet are similar

# Dip-Spin Military applications

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- BAE Fairfield – Magni 550 (zinc underplate) for HMMWV armor kits (4397000)
- AM General – Magni 560 and 565 (19207-12469117)
- BAE Sealy in 2007, FMTV – moved to hex chrome free, cadmium free, performance spec for cadmium replacement (700 hour salt spray) to meet customer requirements (uses Geomet)
  - Fastener supplier provides similar dip-spin coatings
  - Cost virtually same as zinc plate
  - No issues on assembly line, no reports of torque loss or loosening
  - No special tools or procedures

# BAE Combat Systems standard fastener hardware initiative "Clean Hardware"

- Common coating for steel fastener hardware - across programs for logistic, design and manufacture convenience, CAD database
- Meets environmental, torque and corrosion requirements
  - Cadmium and hexavalent chrome free
  - No electroplating to cause hydrogen embrittlement
  - Contains zinc and aluminum – compatible with aluminum and steel
  - 1000 hour salt spray resistance
- Dip Spin coatings are readily available, and cost competitive to hex chrome/zinc
- Although proprietary materials and processes, available from numerous coating suppliers and licensed applicators
  - In wide use by automotive companies for improved corrosion performance and RoHS compliance
  - Dozens of applicators are licensed
  - BAE fastener supplier, Military Commercial Fasteners, assisted in procurement of dip-spin coatings

# “3 Million” part number fastener hardware

- BAE Developed a series of drawings (just happened to start with the number 3 million)
  - 1 drawing for each fastener family
    - Eg, hex head, grade 8, coarse thread
  - 1 drawing covers coating and requirements
    - Able to easily add or change coatings as technology matures
- Partnered with MCF (long time BAE fastener supplier, first experience with dip-spin coatings) to procure “clean hardware” and performed tests to develop drawings
  - Torque tension testing
  - Corrosion testing
  - Thickness testing

# Example drawing

NOTES:		DWG NO 3000001 SH			
		REVISIONS			
1.	APPLICABLE STANDARDS/SPECIFICATIONS: A. ASME Y14.100 B. ASME Y14.5M-1994	REV -	DESCRIPTION INITIAL RELEASE PER EO 2137-STD-002	DATE	APPROVED
2.	THREAD CLASS TO BE 2A AND DIMENSIONS SHALL CONFORM TO TABLE 4, SPEC ASME B18.2.1.	A	EO 2137-STD-008 INC ADCN 181657	2009-03-10	KT GH JK JC
3.	MANUFACTURING OPTIONS: A. SAE J429 OPTION 1. MATERIAL: STEEL, GRADE 8, SPEC SAE J429. 2. MECHANICAL PROPERTIES SHALL CONFORM TO GRADE 8, SPEC SAE J429. 3. HEAT TREATMENT SHALL CONFORM TO GRADE 8, SPEC SAE J429. 4. HEAD MARKINGS SHALL BE IN ACCORDANCE WITH GRADE 8, SPEC SAE J429. 5. QUALITY ASSURANCE OF EACH FASTENER LOT SHALL BE IN ACCORDANCE WITH SPEC SAE J429, SMALL LOT PROVISIONS, EXCEPT WAIVE LOT QUANTITY. B. ASTM A354 OPTION 1. MATERIAL: STEEL, GRADE BD, SPEC ASTM A354. 2. MECHANICAL PROPERTIES SHALL CONFORM TO GRADE BD, SPEC ASTM A354 3. HEAT TREATMENT SHALL CONFORM TO GRADE BD, SPEC ASTM A354 4. HEAD MARKING SHALL BE IN ACCORDANCE WITH ASTM A354. 5. QUALITY ASSURANCE OF EACH FASTENER LOT SHALL BE IN ACCORDANCE WITH SPEC ASTM A354.				
4.	FINISH SHALL BE IN ACCORDANCE WITH COATING DRAWING, 80212-3000099, PARAGRAPH 2.0				
5.					
6.	HEAD MARKINGS SHALL BE APPLIED PRIOR TO FINAL PROTECTIVE FINISH.				
7.					



ALL SHEETS SAME REV

		UNLESS OTHERWISE SPECIFIED DIM ARE IN "in"		CONTRACT NUMBER	
		TOL ON ANGLES $\pm$ ---		DATE OF DRAWING	
		1 PL $\pm$ --- 2 PL $\pm$ --- 3 PL $\pm$ ---		2008-12-01	
		INTERPRET DIM AND TOL PER ASME Y14.5M		DRAWN BY J. RONG	
		THIRD ANGLE PROJECTION		CHECKED J. RONG	
				ENGINEER J. RONG	
				FUND. DESIGN J. CHOUINARD	
				MANUFACTURING J. DORSCH	PROB. ASSUR. WELDING
NEXT ASSY		USED ON		SIZE B	CAGE CODE 80212
APPLICATION				DWG NO 3000001	
				SCALE NONE	WT - - -
				SHEET 1	OF 9

Status RELEASED: Date: 3/31/09

PRO/E

15

# Quality

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- Quality Control issues due to go, no-go gaging issues of thicker coating
  - Despite requirement of “dimensions apply after coating” Magni finishes can add thickness to male thread minor diameter above limit and result in interference when mated with Magni coated female threads
    - Requires careful control of process on small diameter, fine threaded, and small female fasteners
    - Currently < 1/4 inch threaded hardware use stainless steel
    - Small fine threaded can be dip spin coated but need special attention to thickness
    - Identified one supplier that can apply coatings to small hardware and control thickness
    - Washers need to be spread out so they don’t “clump” during cure
- Ideally, fastener suppliers need to anticipate added thickness by undersizing threads
  - This needs high volume
  - Current practice is to start with unplated fasteners

# Real experience on a particular vehicle program.....

- MMPV Panther (engineering ordnance disposal vehicle based on RG33 MRAP) design started in early 2008
- New environmental requirement prohibited hexavalent chrome
- Therefore, determination to go with best available technology
  - dip-spin type
- Accelerated development of “clean hardware” drawings
- Vehicle production had been started months earlier
- Engineering changes to assembly drawings made
- MMPV assembly drawings “redlined” to substitute 3000000 “clean” hardware part numbers
- Vendor Military Commercial Fasteners BAE – York sole fastener supplier brought in
- Determined to institute complete change-over
  - Able to identify which vehicles were “clean”
- Clean hardware breakpoint – June 2009 - changed out all fastener hardware over 1 weekend
  - Training provided to mechanics at plant (Letterkenny Army Depot where most assembly processes occur), posters put up
  - No issues occurred during installation of new fasteners
  - Slightly more difficult to start small threaded fasteners
  - Instances of poor grounding, fixed by moving ground strap



# Environmentally-friendly Fasteners

BAE Systems is replacing old hardware because its yellow/gold finish contains hexavalent chrome, a potentially hazardous material. New "clean" hardware, free of cadmium and hexavalent chrome, is now being transitioned to Medium Mine Protected Vehicles (MMPV) and future vehicles.

The fastener metal has not changed, but the new coating is organic-inoc and aluminum particles are halo-cured. Known as Magni or Geomet, the coating may be silver, black or tan, with a "painted-on" appearance. Though the new hardware offers better resistance to corrosion, the fasteners can be more difficult to install because the baked-on coating is slightly thicker than a plated finish.



Initial finger installation may be more difficult, but nut-tightness and torque values are the same as cadmium-plated screws (unless otherwise indicated).

Dia., in	Threads per inch	Torque, in-lb	
		Min.	Max.
1/4	20	3.6	9.5
1/4	28	9.5	10.5
5/16	18	17	19
5/16	24	19	21
3/8	18	31	35
3/8	24	35	39
7/16	14	49	55
7/16	20	55	61
1/2	13	76	84
1/2	20	85	95
9/16	12	109	121
9/16	18	122	134
5/8	11	151	167
5/8	18	171	189
3/4	10	268	288
3/4	18	299	331
7/8	9	432	478
7/8	14	477	522
1	8	647	715
1	12	709	783



Acceptable Grade 8 Bolt Markings  
Part numbers are 3 million series  
(2000000, 3000000, 4000000, 5000000, 6000000, 7000000, 8000000, 9000000, 10000000, 11000000, 12000000, 13000000, 14000000, 15000000, 16000000, 17000000, 18000000, 19000000, 20000000, 21000000, 22000000, 23000000, 24000000, 25000000, 26000000, 27000000, 28000000, 29000000, 30000000, 31000000, 32000000, 33000000, 34000000, 35000000, 36000000, 37000000, 38000000, 39000000, 40000000, 41000000, 42000000, 43000000, 44000000, 45000000, 46000000, 47000000, 48000000, 49000000, 50000000, 51000000, 52000000, 53000000, 54000000, 55000000, 56000000, 57000000, 58000000, 59000000, 60000000, 61000000, 62000000, 63000000, 64000000, 65000000, 66000000, 67000000, 68000000, 69000000, 70000000, 71000000, 72000000, 73000000, 74000000, 75000000, 76000000, 77000000, 78000000, 79000000, 80000000, 81000000, 82000000, 83000000, 84000000, 85000000, 86000000, 87000000, 88000000, 89000000, 90000000, 91000000, 92000000, 93000000, 94000000, 95000000, 96000000, 97000000, 98000000, 99000000, 100000000, 110000000, 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# OEM Implementation

- US Army has imposed a recent requirement for non hazardous materials and better corrosion performance for their platforms
  - USD John Young memo minimizing hexavalent chrome
  - BAE Engineering Directive to eliminate hexavalent chrome
  - ISO14000 drives minimization of hazardous materials
- New Wheeled and future tracked programs have included this new contract requirement
  - Engineering implements clean hardware for new designs only
    - Clean hardware brought into new programs and new designs
    - Legacy programs continue to use hex chrome
      - CAD database limits parts available for selection by designers
  - Result is that now there are:
    - 2 times as many fastener parts in inventory (to procure, QC, store, transport) for OEM making new and legacy vehicles
    - Different torque for same size fastener
    - Opportunity to mix clean and dirty hardware
    - Additional inventory for readiness and sustainment

# Challenges- Program

- Commingling of clean hardware with existing, common material is forcing programs to identify affected parts with new configuration item identification (part numbers). Each affected installation and part must be revised.
  - Example: Panther FOV identified approximately 500 fasteners/ hardware that are being updated to “clean” within 60 installations.
  - Drawings reviewed by engineering for any effects on torque, conductivity, etc.
- Existing material must be purged and either scrapped or reworked if it cannot be consumed
- Delays in schedule due to supplier’s rework and implementation issues
- Common items not managed by a particular program require coordination and funding to revise/ update (ex: MMPV common with MRAP)
- COTS, Government furnished, proprietary items and configuration items not managed by BAE USCS are in question
- Rework of common documentation to include Work Instructions, Bills of Material, Receiving Inspection documents, Purchase Orders, Tech Manuals, etc. as new part numbers and technical documents are released.
- Simple lack of availability of clean hardware – custom manufactured – not COTS
- Part numbers not recognized across the supply base
- Logistics, spare parts, maintenance instructions, need NSN numbers for new parts

# More Challenges-Engineering

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- Torque equivalent to legacy cadmium plated fasteners, may need adjustment if replacing zinc plated hardware for critical applications
  - Different appearance will alert shop and field personnel to use correct torque
- Not highly conductive, if ground path is via fastener, then adjustment to design or assembly sequence may be needed
  - Testing shows Magni Coating is partially conductive, but how much is needed?
  - Some concern that non-conductive fastener will be used by mistake for grounding applications

# Summary

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- Environmental and Corrosion requirements driving military suppliers (not just BAE) toward new technology
- Industrial, COTS fastener standards not keeping up
- Literature, ARL and limited BAE tests show that specific Dip-Spin coatings offer the best combination of performance with corrosion and environmental compliance – and cost
- BAE made engineering changes to implement clean hardware
- Many challenges to implement clean parts
- MMPV Panther FoV has had no significant technical challenges since going “clean”

*I will always place the mission first.*

*I will never accept defeat.*

*I will never quit.*

*I will never leave a fallen comrade.*

*- U.S. Army Warrior Ethos*

**We Protect Those Who Protect Us**

BAE SYSTEMS